SPECIFICATION

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BULK DIFFUSER FOR FLAT PANEL DISPLAY

BACKGROUND OF THE INVENTION

[0001] This invention relates to optical sheet material and, more specifically, to such sheet material characterized by bulk diffusion of light.

[0002] In backlight computer displays or other display systems, optical films or sheet material are commonly used to direct, diffuse or polarize light. For example, in backlight displays, brightness enhancement films use prismatic structures on the surfaces thereof to direct light along a viewing axis (i.e., an axis normal to the display). This enhances the brightness of the light viewed by the user of the display and allows the system to consume less power in creating a desired level of on-axis illumination. Such films can also be used in a wide range of other optical designs, such as in projection displays, traffic signals, and illuminated signs.

[0003] In current displays systems, for example in Liquid Crystal Displays (LCD), it is desirable to have diffusing components. Examples of the utility of diffusing components include (but are not limited to) masking artifacts, such as seeing electronic components located behind the diffuser film, improved uniformity in illumination and increased viewing angle. In a typical LCD display, diffusion of light is introduced into the backlight assembly by adding separate films (i.e., a stack) that are comprised of a non-diffusing substrate to which a highly irregular, diffusing surface treatment is applied or attached. It is thus desirable to generate diffuse light with out the added cost of separate films.

SUMMARY OF THE INVENTION

[0004]

The invention features a bulk light diffuser material. The bulk light diffuser

material comprises about 95 to about 99.8 percent by weight of polycarbonate and about 0.2 to about 2.5 percent by weight of a particulate light diffusing component, based on the total weight of the polycarbonate and the light diffusing particles. The sheet material has a percent transmittance of at least 70% and a haze of at least 10% measured according to the American Society for Testing and Materials (ASTM) standard D 1003.

[0005] In another aspect of the invention, a backlight display device comprises an optical source for generating light; a light guide for guiding the light therealong including a reflective surface for reflecting the light out of the light guide; and the aforesaid bulk light diffuser material as a sheet material receptive of the light from the reflective surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIGURE 1 is a cross sectional view of a backlight display device including an optical substrate or optical sheet material.

[0007] FIGURE 2 is a graphical representation of two particle size distributions of light diffusing particles introduced into an optical substrate or optical sheet material.

[0008] FIGURE 3 is a graphical representation of the theoretical transmission of light through a polycarbonate film or optical sheet material with diffuser particles introduced thereto according to the particle size distributions of Figure 2, as a function of scattering angle as compared to prior art polycarbonate film.

[0009] FIGURE 4 is a cross sectional view of an optical substrate or optical sheet material receptive of light and diffusing the light emanating therefrom.

[0010] FIGURE 5 is a graphical representation of experimental results of the predicted transmission of light vs the measured transmission of light for PMMA and TOSPEARL ® particles distributed in a polycarbonate film or optical sheet material.

[0011] FIGURE 6 is a graphical representation of experimental results of the predicted haze vs the measured haze for PMMA and TOSPEARL ® particles distributed in a polycarbonate film or optical sheet material.

[0012] FIGURE 7 is a graphical representation of the measured percent transmission of light vs the measured percent haze for matte surface and polished surface PMMA and polished surface TOSPEARL ® particles distributed in a polycarbonate film or optical sheet material.

[0013] FIGURE 8 is a cross sectional view of an optical substrate having prismatic structures of the surface thereof.

[0014] FIGURE 9 is a graphical representation of the measured percent transmission of light vs the measured percent haze for PMMA and TOSPEARL ® particles distributed in a polycarbonate film or optical sheet material according to particle concentration and mean diameter size.

[0015] FIGURE 10 is a three dimensional view of a backlight display device including a stack of optical substrates.

[0016] FIGURE 11 is a three dimensional view of optical substrates oriented such that the direction of prismatic surfaces thereon are positioned at an angle with respect to one another.

DETAILED DESCRIPTION OF THE INVENTION

[0017] In Figure 1 a perspective view of a backlight display 100 device is shown. The backlight display device 100 comprises an optical source 102 for generating light 116. A light guide 104 guides the light 116 therealong by total internal reflection. A reflective device 106 positioned along the light guide 104 reflects the light 116 out of the light guide 104. A first optical substrate 108 positioned above the light guide 104 is receptive of the light 116 from the light guide 104. The first optical substrate 108 comprises, on one side thereof, a planar surface 110 and on a second, opposing side thereof, a prismatic surface 112 (Fig. 8) or may comprise opposing planar surfaces 110 or opposing prismatic surfaces 112. The opposing surfaces may also include a matte finish, for example a surface replicated from a sand blasted, laser machined, milled or electric discharged machine master as well as the planar and prismatic surfaces. The first optical substrate 108 is receptive of the light 116 and acts to turn the light 116 in a direction that is substantially normal to the first optical substrate 108 along a direction *z* as shown. The light 116 is then directed to a second optical

substrate 114 located above the first optical substrate 108 to provide diffusion of the light 116. The second optical substrate 114, which may be sheet material, is receptive of the light 116 from the first optical substrate 108. The light 116 proceeds from the second optical substrate 114 to a liquid crystal display (LCD) 130 (Fig. 10). It will be appreciated that the second optical substrate may also include the aforesaid planar and prismatic surfaces 110, 112.

[0018] As best understood from Figure 10, the backlight display device 100 may include a plurality of optical substrates 108, 114 arranged in a stack as shown. Furthermore, the prismatic surfaces 112 of the optical substrates 108 may be oriented such that the direction of the prismatic surfaces 112 are positioned at an angle with respect to one another, e.g., 90 degrees (Fig. 11). Still further, it will be appreciated that the prismatic surfaces 112 of the optical substrates 108 have a peak angle, α , a height, h , a pitch, p , and a length, l which may have prescribed values or may have values which are randomized or at least psuedo-randomized.

[0019] Haze is the scattering or diffusion of light as light passes through a transparent material. Haze can be inherent in the material, a result of a formation or molding process, or a result of surface texture (e.g., prismatic surfaces). By adding light diffusing particles 128 (Fig. 4), having a characteristic dimension of about 1 to 10 micrometers, to the second optical substrate 114, the diffusion of light emanating therefrom may be improved. The light diffusing particles 128 may be round or irregular in shape, and have a refractive index different from that of the second optical substrate 114. Typical refractive indices of the light diffusing particles 128 are in the range of about 1.4 to about 1.7 and that of the second optical substrate 114 in the range of about 1.45 to about 1.65. The light diffusing particles 128 may be randomly, or at least pseudo-randomly, distributed or oriented in the optical substrate 114, or may be aligned in some deterministic fashion.

[0020]

Suitable light diffusing particles may comprise organic or inorganic materials, or mixtures thereof, and do not significantly adversely affect the physical properties desired in the polycarbonate, for example impact strength or tensile strength. Examples of suitable light diffusing organic materials include poly(acrylates); poly (alkyl methacrylates), for example poly(methyl methacrylate) (PMMA); poly

(tetrafluoroethylene) (PTFE); silicones, for example hydrolyzed poly(alkyl trialkoxysilanes) available under the trade name TOSPEARL ® from GE Silicones; and mixtures comprising at least one of the foregoing organic materials, wherein the alkyl groups have from one to about twelve carbon atoms. Examples of suitable light diffusing inorganic materials include materials comprising antimony, titanium, barium, and zinc, for example the oxides or sulfides of the foregoing such as zinc oxide, antimony oxide and mixtures comprising at least one of the foregoing inorganic materials.

[0021] Figure 2 shows two light diffusing particle size distributions 118a, 118b wherein the frequency of the light diffusing particles is a function of particle diameter (or some characteristic dimension). In a first light diffusing particle size distribution 118a the average particle size is 2.4 micrometers with a standard deviation of 500. In a second light diffusing particle size distribution 118b the average particle size is 4.5 micrometers with a standard deviation of 500.

[0022] Figure 3 shows a graphical representation of the theoretical transmission of light 120, 122 (luminance in Cd/m^2) at 560 nm through a 0.127 mm thick polycarbonate film with light diffusing particles, having a refractive index of 1.49, and a concentration of 1.8% (122) and 1.5% (120) introduced thereinto according to the particle size distributions of Figure 2, as a function of scattering angle, as compared to the actual transmission of light 124, 126 through two prior art polycarbonate films. As can be seen from Figure 3 by selecting a proper refractive index, mean particle size and particle concentration, a transmission can be found that substantially follows that of actual transmission.

[0023]

Table 1 shows data for two types of light diffusing particles suspended in a 0.178mm thick polycarbonate film with a refractive index of 1.59. Typical films are about 0.025 to 0.5mm in thickness but could be thicker or thinner if the application required it. The first light diffusing particle is a polymer comprised of poly(methyl methacrylate), and the second is a polymer comprising hydrolyzed poly(alkyl trialkoxysilane), or a mixture thereof, where "alkyl" is defined as C_1-C_{12} alkyl, preferably methyl. With no light diffusing particles added to the polycarbonate film the integrated reflection is 9.7% and the integrated transmission is 88.4%. As can be

seen from Table 1, in the first exemplary particle size and concentration, by maintaining a constant mean particle diameter (2.4 micrometers), standard deviation (0.24 micrometers) and particle concentration (0.2%), while changing the refractive index of the light diffusing particles from 1.49 to 1.43, the integrated reflection increases from 9.8% to 9.9%, the integrated transmission diminishes from 88.3% to 87.8%. In the second exemplary particle size and concentration, by maintaining a constant mean particle diameter (2.4 micrometers), standard deviation (0.24 micrometers) and particle concentration (2.2%), while changing the refractive index of the light diffusing particles from 1.49 to 1.43, the integrated reflection increases from 11.0% to 16.5% and the integrated transmission diminishes from 86.3% to 78.9%. Thus, lowering the refractive index of the added particulate matter from 1.49 to 1.43 relative to that of polycarbonate film refractive index of 1.59 reduces transmission and increases the reflection of light through the polycarbonate film.

[0024] As can also be seen from Table 1, by increasing the light diffusing particle concentration from 0.2% to 2.2% for a given particle type, where the refractive index of the light diffusing particles is constant, the haze for PMMA increases from 34% to 98% while for TOSPEARL ® the haze increases from 44% to 99%. Thus, increasing the concentration of the light diffusing particles increases the haze of the polycarbonate film. In summary, Table 1 illustrates that PMMA is a good candidate for use as the added light diffusing particles because its addition to the polycarbonate film has the minimal reduction in the integrated transmission from 88.4% to 86.3% while at the same time achieving a percent haze value of 98%.

[t1]

Table 1						
Light Diffusing Material	Refractive Index (n)	Particle Size (diameter in micrometers)	Particle Conc (weight %)	Integrated Reflection (%)	Integrated Transmission (%)	Haze (%)
None	1.59		0.0%	9.7%	88.4%	0%
PMMA	1.49	2.4	0.2%	9.8%	88.3%	34%
PMMA	1.49	2.4	2.2%	11 0%	86.3%	98%
TOSPEARL®	1.43	2.4	0.2%	9.9%	87.8%	44%
TOSPEARL®	1.43	2 4	2.2%	16.5%	78.9%	99%

[0025] Referring now to Figures 5 and 6 experimental results for predicted vs measured percent transmission of light and percent haze are shown. In Figure 5 the PMMA particles (Δ) and the TOSPEARL ® particles (o) show a reasonably good equivalence between the measured and predicted transmission values.

[0026] In Figure 6, the predicted and measured percent haze is calculated from

$$\%Haze = 100 \times \frac{Total\ \ Diffuse\ \ Transmission}{Total\ \ Transmission} \qquad (1)$$

where total transmission is the integrated transmission and the diffuse transmission is the light transmission that is scattered by the film as defined by ASTM D 1003. As seen in Figure 6, the PMMA particles (Δ) show a reasonably good equivalence between the measured and predicted values of percent haze, whereas the TOSPEARL ® particles (o) show a very near or substantial equivalence between the measured and predicted values of percent haze. However, as noted above in Table 1, TOSPEARL ® shows a higher integrated reflection for both particle size distributions than that of PMMA. Thus, for applications that require higher reflection TOSPEARL ® may be preferred.

[0027] Figure 7 is a graphical representation of the experimental measured percent transmission of light through a polycarbonate film relative to their measured percent haze thereof for matte surface (Δ) and polished surface (•) PMMA particles and polished surface (o) TOSPEARL ® particles distributed in the polycarbonate film. The refractive index difference between the polycarbonate film and the PMMA particles is about 0.1, which is optimum for high haze and high transmission values. However, the refractive index difference between the polycarbonate film and the TOSPEARL ® particles is about 0.16 which is larger than that between PMMA and the polycarbonate, leading to lower transmissions for the high haze samples. In Figure 7, several of the PMMA particles (both matte and polished surfaces) show a transmission of greater than 90% and a haze of greater than 80% by controlling the particle concentration, while no TOSPEARL ® particles have a transmission of greater than 90% even for particles with a haze of greater than 80% even by controlling particle concentration. Figure 7 also shows data indicating PMMA polished and silicone polished particles having a transmittance of about 91% and a haze of about 15%. The aforesaid matte and polished surfaces are defined by gloss values according to ASTM standard D523 where the polished surface has a gloss value of over 90 and a matte surface has a gloss value of under 50.

[0028]

Figure 9 is a graphical representation of the measured percent transmission of light through a 0.178 mm thick polycarbonate film vs the measured percent haze thereof for PMMA and TOSPEARL ® particles distributed in a polycarbonate film or optical sheet material according to particle concentration and mean diameter size. In

Figure 9, for PMMA particles, by increasing the particle concentration from 0.2% to 2.2%, while maintaining the mean particle size at either 2.4 micrometers or 5.0 micrometers, the transmission increased, or only decreased slightly, with an increase in haze. In particular, a PMMA particle concentration of 2.2% and a mean particle size of 2.4 micrometers (•) or a PMMA particle concentration of 2.2% and 5.0 micrometers (▲) possesses a measured haze of greater than 80% and a measured transmission of greater than 90%. In contrast, for TOSPEARL ® particles, by increasing the particle concentration from 0.2% to 2.2%, while maintaining the mean particle size at either 2.0 micrometers or 4.5 micrometers, the transmission decreased, even though there was an increase in haze. However, a TOSPEARL ® particle concentration of 2.2% and a mean particle size of 4.5 micrometers (◆), possesses a measured haze of greater than 80% though still possessing a measured transmission of greater than 89%. Also seen in Figure 9 is data indicating a TOSPEARL ® concentration of about 0.2% and a 4.5 micrometer size having a haze of about 15% and a transmittance of about 91%, as well as a PMMA concentration of 0.2% and 5.0 micrometer size having a haze of about 17% and a transmittance of about 91%.

[0029] Figures 7 and 9 thus show that PMMA particles (with both matte and polished surfaces) suspended in a polycarbonate film at a selected particle concentration of about 2.2% and a mean particle size of either 2.4 micrometers or 5.0 micrometers are a good candidate for effecting the necessary light diffusion properties in display devices.

[0030]

Thus, based upon the foregoing description a bulk light diffuser as a polycarbonate film or optical sheet material or optical substrate has been described comprising about 95 to about 99.8 percent by weight of a polycarbonate and about 0.2 to about 5 percent by weight of light diffusing particles, based on the total weight of the polycarbonate and the light diffusing particles. Other components may be present in the polycarbonate compositions in minor amounts, as long as such components do not adversely affect the physical properties of the composition, such that the bulk light diffuser consists essentially of the polycarbonate and the light diffusing particles. Preferably the light diffusing particles comprise a polymer selected from the group consisting of poly(methyl methacrylate), hydrolyzed poly(methyl trialkoxysilane), and mixtures thereof. The sheet material has a percent transmittance

of at least 70% and a haze of at least 10% measured according to ASTM standard D 1003-00.

[0031] The description of the invention herein discloses a polymer particle concentration ρ , a sheet material thickness, t, and a mean particle size, s , to achieve a preferred sheet material having optical properties of at least 70% transmission and at least 10% haze, a more preferred sheet material having optical properties of at least 90% transmission and at least 80% haze, and a most preferred sheet material having optical properties of at least 90% transmission and at least 90% haze, for a polymer such as a poly(acrylate), a poly(alkyl methacrylate), a hydrolyzed poly(alkyl trialkoxysilane), or a mixture thereof, wherein alkyl is defined as C_1 -C_{12} alkyl, and the particles are suspended within a polycarbonate. However, it will be understood by those skilled in the art that the aforesaid particle concentration ρ , sheet material thickness, t, and mean particle size, s , can be manipulated either separately or in combination so as to achieve the preferred, more preferred and most preferred transmission and haze.

[0032] Embodiments of the bulk light diffuser material as a polycarbonate film or optical sheet material have been described with respect to backlight displays or the like. Such bulk diffusion may also be attained by adding the light diffusion particles to either the upper or lower substrate containing liquid crystal material, or both in an LCD. This can result in increased view angle and decreased artifacts from pixel boundaries. The bulk diffusion of light may also be accomplished by adding the light diffusion particles to the reflective surface 106 positioned along the light guide 104 or to the light guide 104 in an edge-lit backlight or frontlight assembly. The optical sheet material can replace surface texture type of diffusers in existing backlight devices or may be included in such diffusers as well as in brightness enhancement films or light turning films.

[0033]

Any references to first, second, etc. or to front and back, right and left, top and bottom, upper and lower, horizontal and vertical, or any other similar type of designation indicating a relative position between two or more quantities or objects are, unless noted otherwise, intended for convenience of description, not to limit the present invention or its components to any one positional or spatial orientation. All

dimensions of the components in the attached Figures can vary with a potential design and the intended use of an embodiment without departing from the scope of the invention.

[0034] While the invention has been described with reference to several embodiments thereof, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

[0035] What is claimed is: